



Age of the Universe:
13.7 Billion Years

COSMIC TIMES

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Home Edition

Size of the Universe:
94 Billion Light Years

Faster Walk on the Dark Side

There is new evidence that a mysterious anti-gravity energy is speeding up the expansion of the universe. This energy is called dark energy and makes up almost three-quarters of the universe. All that we know about this dark energy is that it works against gravity and causes galaxies to move apart faster than expected.

The new evidence is the discovery of an effect dark energy has on light from the earliest universe. This very old light started its journey across the universe just 380,000 years after the Big Bang. Its energy has cooled down to microwave energy in the 13 billion years since. Today we observe the light as cosmic microwave background (CMB) radiation. Scientists noticed something called the Integrated Sachs-Wolfe (ISW) effect acting on the CMB.

ISW was named after Rainer Kurt Sachs and Arthur Michael Wolfe, who first described it in 1967. Its effect on the CMB was recently confirmed by scientists around the world. The three teams who did the work were Stephen Boughn of Haverford College, Robert Crittenden of the University of Portsmouth and the WMAP team led by NASA's Charles Bennett. Helping Bennett were astronomers of the Sloan Digital Sky Survey team who worked with Pablo Fosalba and his coworkers of the Institut d'Astrophysique de Paris.

These scientists pulled together valuable data on the large-scale structures of the universe and data on light from the early universe (CMB) to reach their conclusions. The data included observations from visible light, X-ray, radio, and microwave telescopes.

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Seeds of Modern Universe

Cosmic researchers now have the clearest view ever of the universe's early structure – clusters of galaxies, and clusters of clusters of galaxies. The better view comes in the form of super-sensitive temperature data of the Cosmic Microwave Background (CMB) collected by the Wilkinson Microwave Anisotropy Probe (WMAP). The CMB is the afterglow (left-over light) of the Big Bang.

WMAP has greatly improved on the fuzzier, first map of the CMB made in 1993. That first map was made with data from NASA's Cosmic Background Explorer satellite (COBE).

What WMAP has now confirmed are "peaks" of the Big Bang shockwaves in the CMB. These were first observed in 1999 and 2000 with ground-based instruments. These observations lead to the conclusion that the geometry of the universe is flat. What that means is that in space, on a large scale, parallel lines would stay parallel.

WMAP's measurement of these peaks gives the amount of normal

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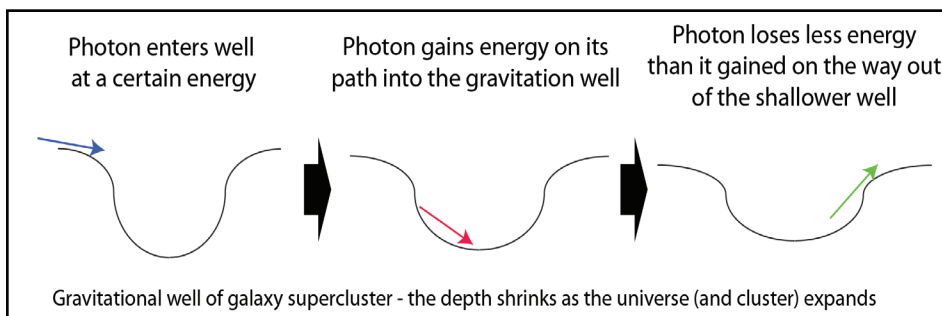


Illustration of the Integrated Sachs-Wolfe effect.

Here's how the ISW effect works. Gravity is a property of matter. Matter exists in "gravity wells" in space-time. More matter makes a deeper well. If there is no change in the depth of a well when light crosses it, then the well has no effect on the energy of the light. If dark energy stretches out deep wells of gravity into shallow dents, then CMB light crossing the well will change its energy. The data collected by these scientists show slight changes in the energy, which provides evidence of dark energy.

This is good news to two teams of astronomers who discovered the first signs of dark energy in 1998. They discovered galaxies were moving faster than they should be. They learned this by measuring the speed at which very distant Type Ia supernovae (in the galaxies) moved away from our galaxy. The teams were the Supernova Cosmology Project team at Lawrence Berkeley National Lab and the international High-z Supernova Search Team. They meant to measure the rate at which the expansion of the universe was slowing down. Instead, the supernovae showed the distance between Earth and the most distant galaxies was growing faster and faster. It was like some unknown invisible force of "dark" energy was working against the force of gravity and pushing galaxies apart. More than that, the expansion sped up five billion years ago.

The researchers chose to name this force dark energy. This should not be confused with dark matter, which is another puzzling problem in cosmology.

As for what dark energy is, that's anyone's guess right now. There are at least half dozen theories, and none of them seem very close to an answer. ♦

BIGGEST MYSTERY

WHAT IS DARK ENERGY?

The farther we look into the cosmos, the less sense it makes. That's the feeling of scientists now struggling with the problem of dark energy. This unknown force is the dominant stuff of the universe, and at this point it is a big mystery.

There are several theories being proposed to explain dark energy. So far, testing these ideas has been very hard to do. To do this, they need new scientific instruments to search deeper into the universe.

Right now, the only way to talk about dark energy is to say what we know it does. It creates more space, new space by pushing galaxies further apart. This makes the entire universe grow larger at a faster rate. In the late 1990s, studies of distant supernovae showed space was expanding faster than expected.

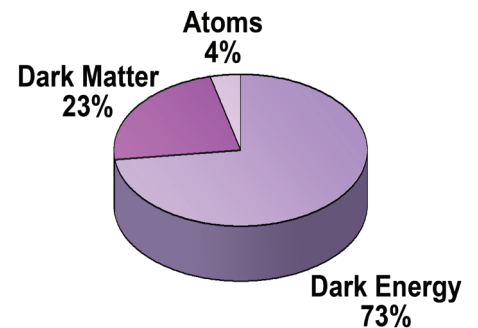
There was one big hint that dark energy existed even before it was discovered by astronomers. The great Albert Einstein had included an "anti-gravity" effect called the Cosmological Constant in his Theory of General Relativity to make it work correctly. After Edwin Hubble discovered the universe was expanding, Einstein and other scientists viewed this as an annoying "fudge factor" that had no connection to the real universe.

Later researchers described the Cosmological Constant as an underlying background energy. That energy might exert some kind of

pressure on the cosmos. Unfortunately, the theory predicts the energy ought to be much stronger than dark energy appears to be.

Another idea for dark energy is something called quintessence. The word is the same as the ancient Greek term for a mysterious fifth element beyond earth, air, fire, and water. Unlike the cosmological constant, the modern theory of quintessence is an energy field that pushes particles apart. It can also lessen over space and time. This is handy because observations suggest that dark energy has only been in effect for about the last 5 billion years – so its effect is not constant.

Scientists need to learn much more about dark energy's impact on the universe to test their theories. The only way to do that, of course, is with more data from the universe. ♦



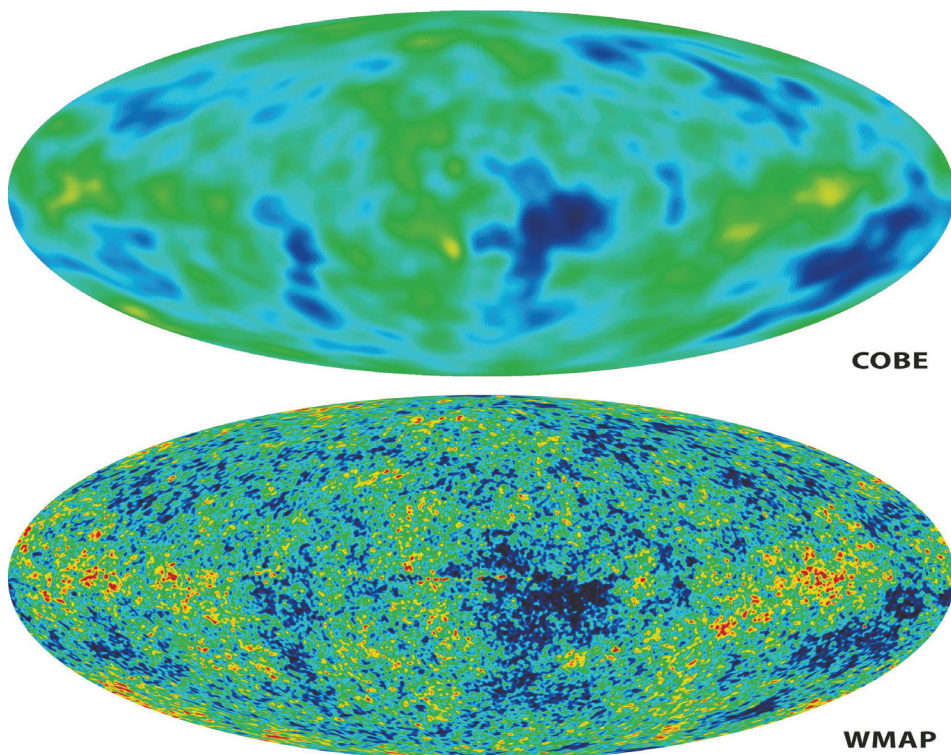
According to astronomers, 4% of the universe is made up the familiar atoms, 23% is made up of dark matter, which does not emit or absorb light, and 73% is made up of dark energy, which is causing the expansion of the universe to speed up.

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and dark matter in the universe. This information, combined with knowing the universe is flat, shows as-

tronomers what the total matter and energy composition of the universe must be. Normal matter makes up 4% of the universe and dark matter

23%. Therefore, dark energy makes up 73%. This falls right in the range of the amount of gravity-repelling dark energy discovered in 1998.



Comparison of the COBE (top) and WMAP (bottom) results. WMAP has a higher sensitivity to small temperature changes than COBE. From these fluctuations astronomers can determine properties of the universe.

WMAP has also, for the first time, discovered the polarization of light everywhere in the CMB. This is important because it helps us understand what happened during the first split second after the Big Bang. That's when the universe puffed up like a lump of bread dough. That moment astronomers call inflation caused tiny variations in the original Big Bang to form slight differences in temperature seen in the CMB. Those differences, in turn, are thought to be the seeds of today's gigantic clusters of galaxies which are strung together like cobwebs throughout the universe.

Researchers are now comparing and combining the new WMAP data with a range of other cosmic measurements to uncover a new understanding of the universe's past, present, and future. ♦

First Light Wins Nobel

John Mather and George Smoot have been awarded the 2006 Nobel Prize in Physics for their 1992 discoveries about the cosmic microwave background – the remaining light from the beginning of the universe as seen today.

According to those presenting the award, “these measurements marked the start of cosmology as a precise science.”

Using data from the space-based Cosmic Background Explorer

(COBE), a team led by Mather and Smoot figured out the details of how the universe has cooled. They measured the energy of light from this background and found that it matched predictions from the Big Bang theory perfectly. They also found the very slight variations in the microwave light. Had these tiny variations been missing, it would have been hard to explain how the universe got its present structure. Later experiments have fine-tuned the COBE data, but the basic discovery of the variations remains. ♦



Dr. John C. Mather

4 Journey to Cosmos' Dark Heart

Scientists are working to shed some light on the darkest mystery in the universe: dark energy.

NASA and the US Department of Energy are considering three concept studies to become their Joint Dark Energy Mission (JDEM). JDEM could launch as early as 2013.

JDEM's goal is to sharpen and double-check the distance measurements to Type 1a supernovae. This information should provide important clues to how fast the universe has expanded during the history of the universe.

Type 1a supernovae are used to determine the distances to other astronomical objects. By observing a large number of these "standard candle" supernovae in galaxies far and near, researchers hope to find out just how quickly those galaxies are flying away from us.

The three concept studies are the Supernova Acceleration Probe (SNAP), the Advanced Dark Energy Physics Telescope (ADEPT), and the Dark Energy Space Telescope (Destiny). Each of these space-based observatories look at supernovae in different ways.

SNAP would use an optical/infra-

red telescope with light detectors. These detectors are similar to charge-coupled devices (CCDs) used in digital cameras. With a billion pixels, SNAP's detector is a thousand times stronger than any handheld camera. SNAP would detect around 2,000 Type 1a supernovae each year over a wide range of distances. That's about 200 times more supernovae than are now detected each year.

ADEPT would use a near-infrared telescope to locate 100 million galaxies and 1,000 Type 1a supernovae. These will be compared to the very small temperature differences in the Cosmic Microwave Background. This should reveal how the earliest galaxies match up with the earliest clumps of matter and how dark energy has changed the distribution of matter since then.

Destiny would have a near-infrared telescope designed to detect 3,000 Type 1a supernovae over two years. It would also spend a year carefully studying a large area of the sky. This would gather new data on changes in the distribution of matter in the cosmos since the Big Bang. Both parts of Destiny's mission will be ten times more sensitive than similar ground-based instruments. ♦

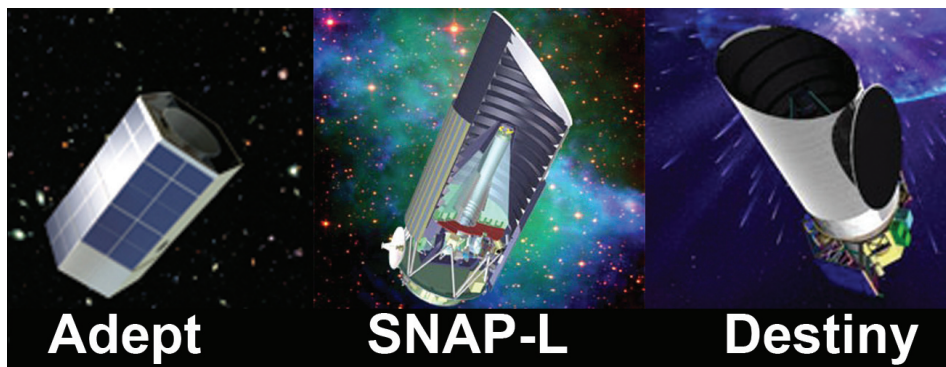
Sorting out Dark Stuff

There's good news and bad news about the universe. The bad news is that the matter which makes up everything that's visible – the Sun, the Earth, humans, everything we can directly detect – adds up to just 4 percent of the known universe. The good news is that we humans are beginning to get a handle on what makes up the rest of it.

The more abundant matter in the universe – dark matter – doesn't rule either. It makes up just 23 percent of the universe. This is dwarfed by the most abundant part of the universe – dark energy. Dark energy is 73 percent of the universe. While both are mysterious, and both have been dubbed "dark" because they can't be directly sensed, they are very different from each other.

Dark matter is the universe's "missing mass." It does not interact with normal matter, except to tug on it with gravity. Dark matter was first proposed in the 1930s by astronomers. They discovered that the amount of visible matter in galaxies wasn't enough to account for the measured gravitational effects of the galaxies on each other. Dark matter is currently thought to be a kind of cold particle that interacts extremely weakly with both atoms and light.

Dark energy, on the other hand, is a stranger idea. We can tell it exists, because it flings everything else apart. This odd energy is right now creating more space out of nothing and pushing everything farther apart at a faster rate. And that's good news too, if you like privacy. ♦



Artist conceptions of the 3 JDEM missions. (Credit: Johns Hopkins, Lawrence Berkeley Lab, NASA/DOE)